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Benefit of wakeful resting on gist and peripheral memory retrieval in healthy younger and older adults

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Abstract

Retrieval is greater if new learning is followed by a period of wakeful rest, minimising the likelihood of retroactive interference. It is not known if this benefit extends to recollection of both gist and peripheral details, nor whether age affects the benefit of wakeful resting in either of these types of recollection. 45 younger and 40 older adults were presented with prose passages for later recall followed by a period of either interference or wakeful resting. Younger participants outperformed older participants in remembering peripheral details, but not on gist memory. Wakeful resting led to higher overall recollection in both age groups, both for gist and for peripheral details. Also, wakeful resting was more beneficial for gist than peripheral memory in older but not younger adults. We discuss these novel findings and their theoretical implications for a memory consolidation account of the benefits of wakeful resting.

Keywords: episodic memory, retroactive interference, gist, ageing, memory trace, memory consolidation.

1. Introduction

Retroactive Interference (RI) occurs when new information processed after initial learning impairs the recollection of previously encoded material [1]. Several studies have reported that wakeful resting, between encoding and retrieval, minimises the likelihood of RI and improves verbal and non-verbal memory performance in healthy young adults [2,3] as well as in older people [4,5] and in amnesic patients [6–9]. Studies with rodents have replicated the benefits of minimal interference on memory task performance[10,11].

What it is still unclear is whether all to-remembered-material benefits from wakeful resting, or whether differential effects of wakeful resting could be observed for different memory traces. It is known that central elements (gist) of study material are generally more likely to be retained [12–14], whereas detailed or secondary (peripheral) information tends to be forgotten more consistently and rapidly [15,16].

Nevertheless, the role of post-encoding behavioural state in relation to gist and peripheral memory recollection is under-investigated. A recent study by Craig and Dewar [17] suggested that awake quiescence protects the peripheral details as well as the central elements of new memory traces on a picture recognition task in young adults. However, it is not known if this is specific to visual material, or whether the pattern would generalise to other modalities of material, such as verbal.

Furthermore, the role of age in memory recollection of gist and peripheral verbal traces after interference or wakeful resting has never been explored. Although a handful of studies have attempted to compare memory recollection performance of older and younger adults while controlling post-encoding behavioural state [4,5], no study so far has compared these effects for memory of central (gist) and secondary (peripheral) material between older and younger groups. The present study was designed to fill these gaps in the literature.

We investigated whether the effect of wakeful resting has a differential impact on gist and peripheral verbal memory traces across two different age groups (younger and older adults). Central events (gist) and peripheral details were integrated in a set of storylines previously employed in studies on memory [16,18]. Given that no studies have ever attempted to address our research question, no a-priori hypotheses were postulated.

2. Methods

2.1 Participants

A sample of 45 younger adults (11 men, 34 women) and a sample of 43 older adults (16 men, 27 women) were recruited from the general public to take part in this experiment.

The ages of the younger adults ranged between 19 and 36 years (M = 23, SD = 3.40) and their years of formal education ranged between 14 and 23 years (M = 17.22, SD = 1.64). The older adults ranged from 65 to 88 years of age (M = 73, SD = 5.45), with years of education ranging from 8 to 22 years (M = 15.75, SD = 3.51). The age limits chosen for the two groups of participants were 19-40 for younger adults (early adulthood) and +65 years of age for older adults (late adulthood).

The older adults were initially assessed with the Montreal Cognitive Assessment (MoCA) [19] to screen for low cognitive functioning. Two participants from this group were excluded for abnormal performance on the MOCA (score < 26) while another was excluded due to technical problems during the experiment. The mean MOCA score of the included participants was 28.27 (SD =1.43). Older participants were also tested on the National Adult Reading Test (NART) [20], which was used as a proxy measure for premorbid intelligence. Raw scores ranged from 28 to 50 (M = 46.55, SD = 3.92), while IQ predicted equivalent scores ranged from 109.74 to 128 (M = 125.35, SD = 3.17). The pre-determined cut-off score was 10, equivalent to a predicted Mini-Mental State Examination (MMSE)[21] score of 26 or above [22]; therefore no participant was excluded due to low NART scores. Both MoCA and NART were administered to make sure that older participants were not suffering from incipient cognitive decline. None of the older participants presented with any known hearing loss that could hamper their performance on the task.

English as a first native language was a requirement for taking part in the study and participants were offered a small honorarium. Ethical approval was obtained from the PPLS Research Ethics panel of the University of Edinburgh (Ref No: 221-1718/6).

2.2 Material

The present study investigated gist and peripheral episodic memory recall after interference and wakeful resting conditions, based on a set of 13 narratives designed by St-Laurent et al.[18], and using the scoring system proposed by Sekeres et al. [16]. Each story comprises five sentences and describes a single episode, with the total number of words ranging from 55 to 77. One male and one female English native speaker were recorded reading six and seven stories each respectively, for auditory presentation to participants.

Each story was assigned a score for gist and peripheral memory. For instance, for a story about a group of kids playing a prank on a car driver (see Appendix), remembering "a group of kids walking down the street" would be considered gist, whereas the fact that the kids were "bored" would be considered a peripheral memory.

With the aim of determining an optimal number of narratives to be presented at encoding, a pilot study was run with four volunteers aged 22-31. They were tested with 2, 3, 4 and 6 narratives to assess the presence of ceiling or floor effects. The procedure for pilot testing was identical to that described in the Experimental Procedure (Section 2.4).

Preliminary piloting suggested that to avoid floor or ceiling effects three narratives was an optimal number per participant.

In keeping with previous studies [2,4], a spot the difference test, displayed on a monitor, was used as interference task between encoding and retrieval. The pictures represented natural and urban landscapes taken by the first author in different countries. Participants were informed to look at pairs of pictures and spot up to three subtle differences between them. The differences were created by removing details from the pictures (e.g., a window from a building) with a photo editor programme.

2.3 Design

Healthy younger and older adults were tested in two experimental conditions (interference and wakeful resting). Their recollection of the to-be-remembered material was scored separately for central gist and peripheral details. A 2x2x2 factorial ANOVA design was employed, with age (younger vs older) as a between-subjects factor, and interference condition (interference vs wakeful resting) and memory trace (gist vs peripheral) as within-subjects factors. Memory score was the dependent measure. Statistical analyses were computed with R.

2.4 Experimental Procedure

The stimulus presentation was conducted with E-Prime 2 (version 2.0.10.242, E-Studio, Psychology Software Tools Inc.) and it included instructions and recording.

Participants were tested throughout the day according to their availability. After being informed that the experiment was about memory, participants were told to listen carefully to three stories through headphones. The number of stories narrated by a male or a female voice was matched between conditions for each participant, and counterbalanced across participants (i.e., two stories with a male voice and one with a female voice for every condition and vice versa). Overall, each participant was presented with six narratives, three for the interference condition and three for the wakeful resting condition. Each participant heard three stories in the interference condition, and the other three stories in the wakeful resting condition. The assignment of stories to condition was counterbalanced across participants. The order of the experimental conditions was also counterbalanced, so that half of the participants in each group were exposed to the interference and then the wakeful resting condition, whilst the other half were exposed to the opposite order. The encoding part of the experiment was the same for both conditions.

After hearing the narratives, participants were assigned either to the interference or the wakeful resting condition, according to the criteria detailed above. In the interference condition participants were asked to perform the spot the difference task for 10-minutes before retrieval. The armchair used during the wakeful resting condition was placed inside a black box and surrounded by a black curtain to minimise interference. After being told to sit and rest for nine minutes, the experimenter pulled the curtain and switched off the light while walking out of the room. The participants were then asked to complete the spot the difference task for one minute to minimise the potential effects of rehearsal. In the spot the difference task, participants were exposed to 22 pairs of pictures during the interference condition; three pairs of pictures were shown in the wakeful resting condition. Each pair of pictures was displayed on the screen, one next to the other, with up to 3 differences to be spotted within 25 seconds. After an interval of 20 seconds, red circles appeared on the screen to reveal the differences. Participants were told to verbally report when a difference was spotted and to touch the screen at the location of the difference. The experimenter was in the room while participants performed this task to make sure that they engaged with the task. The performance on this interference task was not formally assessed.

The retrieval procedure was identical for both experimental conditions. Participants were asked to recall as much as they could from each of the three stories they had listened to, while being recorded through the microphone attached to the headphones. A maximum of one minute was allowed for recalling each story. Before the retrieval recording took place, the experimenter withdrew from the testing room, so as not to influence the participants.

Between the two experimental conditions, participants were allowed a brief pause to rest. The study took approximately forty-five minutes, including a debriefing at the end, whereby the rationale of the study was explained. A summary of the experimental procedure is shown in Figure 1.

----- Insert Figure 1 about here -----

Following Sekeres et al., [16], gist scores were assigned to a precise recall of "what happened" during the story, such as details about the context of the event, the people present, dialogue and actions. Peripheral scores were considered as specific details perceived through the senses, such as the appearance of people ("awkward young man"), relative position of actors ("his mum standing behind him"), position of protagonists in relation to objects ("the boy sitting on the handlebars"), facial expressions ("the man behind the counter gave her an angry look"), motion qualifiers ("at full speed") and sounds ("a car crash sound") (see Appendix). For each individual, the score entered into the analysis for each experimental condition (interference vs wakeful resting) was the sum of the memory scores obtained for the three stories.

2.5 Scoring Procedure

Participants' scores for gist and peripheral recall were based on the criteria reported in the Scoring Manual for Complex Episodic Memories [23] and the studies from which the narratives were adopted [16,18]. Each memory was broken down into meaningful units of information that contained a score for gist (*story details*) and peripheral (*perceptual details*) memories. Candidates were recorded only once for each story and a score for both gist and peripheral details was obtained from each narrative.

3. Results

At debriefing, none of the participants reported that they had fallen asleep during wakeful resting. Seven younger participants reported items not presented in the original narratives (i.e., false memories), three in the interference and four in the wakeful resting condition. In the group of older adults, six participants produced instances of false memories, four in the interference and two in the wakeful resting condition. Within the older sample, three participants in the interference condition recalled an item from one narrative while attempting to retrieve another narrative (i.e., intrusion) but no participants made multiple intrusions. No points were deducted for false memories or intrusions.

In the older adults' group, two participants (participants 2 and 14) scored at floor in both gist and peripheral memory after interference, whereas none of the older adults scored zero for gist or peripheral memory after wakeful resting. In the younger adults' group, none of the participants scored at floor after interference, while one participant scored zero for peripheral memory after wakeful resting (this participant also reported false memories).

The mean gist and peripheral scores achieved by the two groups are shown in *Figure 2*.

----- Insert Figure 2 about here-----

An ANOVA revealed a significant main effect of age, $F(1, 83) = 5.07$, $p = 0.02$, $\eta_p^2=0.05$, meaning that younger adults had a better recollection than older adults, $M = 1.31$, 95% CI [0.15, 2.46]. A significant main effect was detected for condition, $F(1,83) =34.28$, $p <0.001$, $\eta_p^2= 0.29$, with higher memory scores in the wakeful resting condition compared to when participants were exposed to interference condition, $M = 2.23$, 95% CI [1.47, 2.99]. Unsurprisingly, there was a significant main effect of memory trace, $F(1,83) = 743.87$, $p < 0.001$, as gist and peripheral were scored on different scales, so are not directly comparable.

A significant interaction was observed between age and memory trace, $F(1,83) = 7.47$, $p = 0.007$, $\eta_p^2= 0.08$. Post hoc pairwise comparisons were performed to further interpret this interaction. Gist memory scores were not significantly different between older and younger participants, $t(111) = -1.00$, $p = 0.74$, $M = 0.64$, 95% CI [-.71, 1.99], whereas peripheral memory scores were significantly poorer in older than in younger participants, $t(111) = -3.13$, $p = 0.01$, $M =1.98$, 95% CI [1.1 , 2.86].

There was also a significant interaction between memory trace and condition, $F(1,83) = 6.98$, $p = 0.009$, $\eta_p^2= 0.07$. According to post-hoc pairwise comparisons, gist memory scores were significantly higher in wakeful resting than interference condition, $t(165) = 6.4$, $p <0.001$, $M = 2.97$, 95% CI [1.72, 4.22]. Similarly, peripheral memory scores were significantly higher in wakeful resting than interference condition, $t(165) = 3.24$, $p = 0.007$, $M = 1.54$, 95% CI [0.64, 2.44].

A significant three-way interaction between age, memory trace and condition was observed, $F(1,83) = 4.00$, $p = 0.04$, $\eta_p^2= 0.04$. To further interpret this interaction, the wakeful resting benefit was calculated for older and younger participants, for gist and peripheral scores separately, by subtracting the sum of memory scores obtained in the interference condition from that obtained in the wakeful resting condition. The average wakeful resting benefit for the two age groups is depicted in Figure 3.

----- Insert Figure 3 about here-----

A follow-up ANOVA with age as a between-subjects factor, memory trace (gist and peripheral) as a within-subject factor, and wakeful resting benefit as the dependent variable, was performed. This found non-significant main effect of age, $F(1,83) = 0.53$, $p = 0.46$, $\eta_p^2 = 0.01$, meaning that older and younger adults did not differ significantly in the overall benefit obtained from wakeful resting, $M = 0.56$, 95% CI [-0.73,1.85]. The main effect of memory trace was significant, $F(1,83) = 6.98$, $p = 0.009$, $\eta_p^2 = 0.07$, showing an overall greater benefit of wakeful resting for gist than for peripheral scores, $M = 1.41$, 95% CI [0.14, 2.68].

The interaction between age and memory trace was also significant, $F(1,83) = 4.00$, $p = 0.04$, $\eta_p^2 = 0.04$. Post-hoc pairwise comparisons revealed that whereas the wakeful resting benefit scores of younger adults in gist and peripheral conditions did not differ significantly, $t(83) = 0.54$, $p = 0.94$, $M = 0.4$, 95% CI [-1.34, 2.14], the benefit score for older adults was greater for gist than for peripheral memory, $t(83) = 3.26$, $p = 0.01$, $M = 2.52$, 95% CI [0.66, 4.38]. Thus, older adults seemed to benefit more from wakeful resting in gist than in peripheral memory whilst this differential benefit could not be detected in the younger group.

After an unpaired *t*-test revealed a significant difference between the years of education between older and younger adults, $t(1,83) = 2.51$, $p = 0.01$, years of education were entered as a covariate in the original main ANOVA design. The main effect of age remained significant when covarying years of education, $F(1,82) = 5.18$, $p = 0.02$, and the pattern of other statistical outcomes was also unchanged.

4. Discussion

The main results from this study replicated the finding that younger participants have better recollection than older participants and that wakeful resting improves recollection [2-4, 17]. Episodic memory recollection of both gist and peripheral memory scores was significantly higher after the participants of both age groups were exposed to wakeful resting. The benefit to peripheral memory indicates that wakeful resting also enhances the recollection of details [17]. This represents a novel finding as it was observed with verbal material (narratives).

Previous research has found that wakeful resting provides an ideal condition to increase consolidation , as elements of an encoded narrative can be replayed more often than in a condition of cognitive engagement [8,24–25]. The addition of one minute of spot the difference task at the end of the quiet resting period makes it unlikely that the observed effect could be due to intentional continuous rehearsal of the verbal material in the wakeful resting condition. Moreover, previous studies [4, 26] reported beneficial effects of wakeful resting even when the material to be remembered would be difficult to verbally rehearse, making it unlikely that the observed effect is due to verbal rehearsal. Other studies observed similar effects even when participants fell asleep during the procedure, making active rehearsal an unlikely explanation [6,8,27] .

A possible alternative account for the findings of this study considers that the experimental procedure may have caused some retrieval competition within the verbal material (three narratives) presented at encoding [28-30]. Such competition would predict that material from different stories be retrieved instead of items from the target story. However, this is unlikely as only three participants, from the older group, made an intrusion, and nobody made multiple intrusions.

The observed behavioural boosting of memory after wakeful resting has been accounted for in terms of consolidation [1,8,31]. The consolidation hypothesis has been supported by neuroimaging [25,32] as well as animal studies [11,24,25]. The outcome of the present study, showing that reducing the amount of sensory input immediately following encoding enhances recollection [33], is in line with the memory consolidation account [4,26,27,34].

Although extant literature consistently demonstrated a decline in episodic memory retrieval in older age [35], memory for central events (gist) and peripheral details (peripheral) decline differently across the lifespan [14]. Specifically, secondary details are more likely to be forgotten, especially by older people. In the present study, participants from both age groups had similar gist scores, meaning that memory for central events were not markedly affected by age, but an age difference between groups was found for peripheral scores, whereby younger participants retained significantly more peripheral details than older participants.

Previous research [1,5,36,37] maintained that younger participants tend to build stronger memory representations than older adults. This suggests that healthy older individuals should be more vulnerable to interference between encoding and retrieval. However, our results confirmed this age effect only for peripheral memory, whilst participants from both age groups were equally affected by post-encoding interference in the gist memory condition. Further analyses showed a greater benefit from wakeful resting in the gist scores compared to peripheral memory scores in older adults. This result cannot be accounted for in terms of floor effects in the older group's performance, as only two participants scored at floor, one for each type of memory trace. This outcome was not predictable, as it would have been equally possible to postulate that wakeful resting would have benefitted weaker memory traces more than stronger ones, differentially boosting peripheral memory.

This study has some caveats. The lack of immediate recall does not allow us to infer whether the age difference in peripheral memory scores was due to a shallower encoding when the verbal material was exposed to the participants, rather than weaker consolidation. A further limitation of this study is that the sample of older adults may not be entirely representative of the general population (the average predicted IQ on NART and the years of education of these participants were rather high). Additionally, because we did not assess performance on the interfering task (spot the difference), we cannot assess whether engagement with this task is associated with subsequent memory retrieval, but this could be an interesting question for future studies.

The present findings indicate that memory recall for gist and peripheral details of short stories is improved by a period of wakeful resting. For older adults, the beneficial effect of wakeful resting is greater for gisting than for remembering peripheral details.

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Disclosure statement

No potential conflict of interest is reported by the authors.

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Appendix

Sample of narrative scoring of participants after interference and wakeful resting

<u>Story 3: Boys Faking Car Accident</u>

A group of bored kids are walking on the sidewalk. Cars on the street have stopped at a red light.

One boy signals his friend to get ready.

With his foot, he pushes down on a car's bumper.

Simultaneously, his friend hits a garbage lid with a stick, making a car crash sound.

The car's driver storms out and yells at the driver behind him, while the boys watch in glee.

Gist scores (8)

Group of boys walking down street

Cars are stopped

Boy steps on bumper of stopped car

Front driver thinks he has been rear-ended

Front driver gets out of car

Front driver yells at driver behind him

Rear driver gets out of his car

Boys laugh

Peripheral scores (6)

Bored kids

Sidewalk

Red traffic light

Simultaneously

Garbage lid with a stick

Watching in glee

<u>Participant 7</u>

Interference

Two children were walking on the street (**Gist**) and crossing the road. A car came and one of the boys hit a garbage (**Per**) bin and it made a sound of a car crash (**Gist**).

Gist score: 2/8

Peripheral score: 1/6

<u>Participant 25</u>

Wakeful resting

The first story was about a group of bored (**Per**), I think they were all boys, they were walking (**Gist**) on the sidewalk (**Per**) and there are cars ahead of them stopping (**Gist**) at the red light (**Per**). Once the boy signalled to the other, and then he puts his foot on the fender, no the bumper of the car (**Gist**) while his friend hits the lid of a trash can nearby (**Per**). So the guy in that car gets out (**Gist**) and starts yelling at the person in the car behind (**Gist**) because he thought he had hit him (**Gist**). The kids laugh (**Gist**) watching in glee (**Per**).

Gist score: 7/8

Peripheral score: 5/6

Figure 1

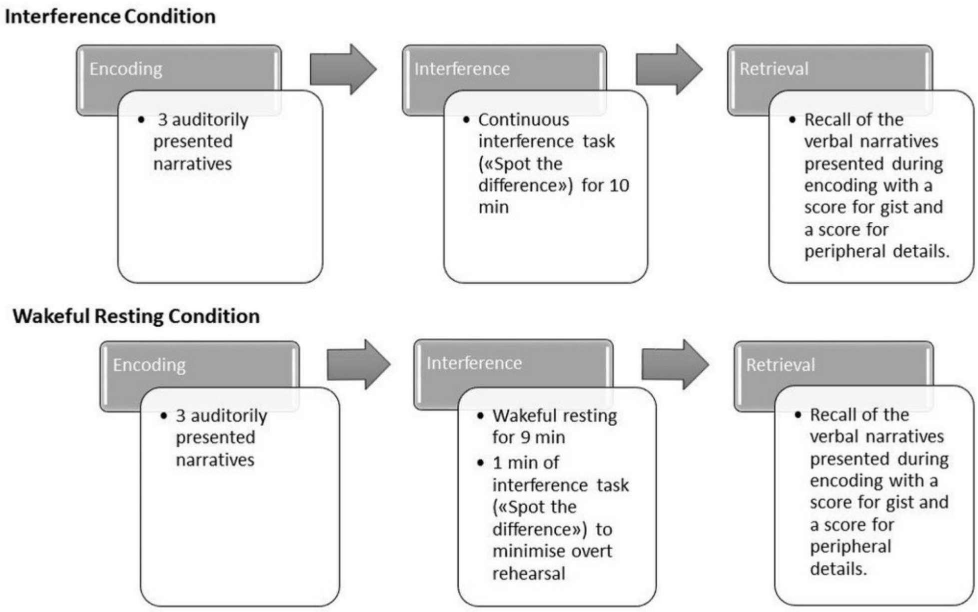

Figure 2

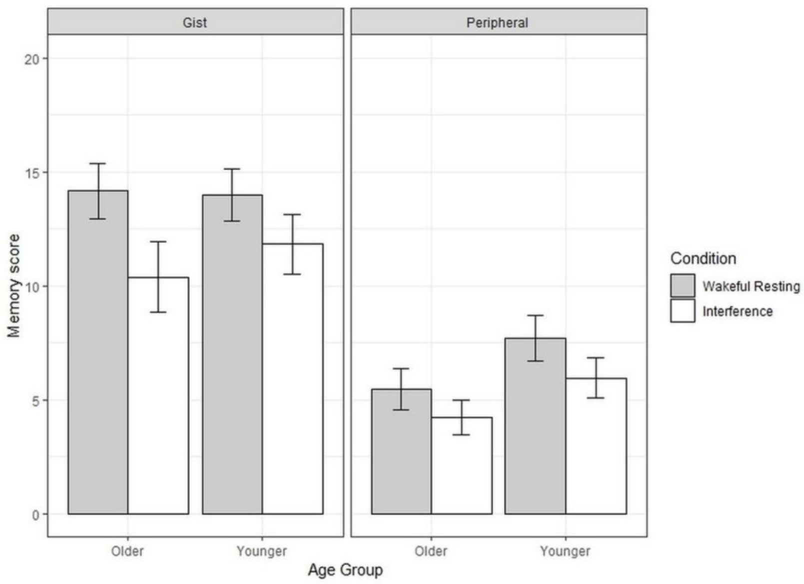

Figure 3

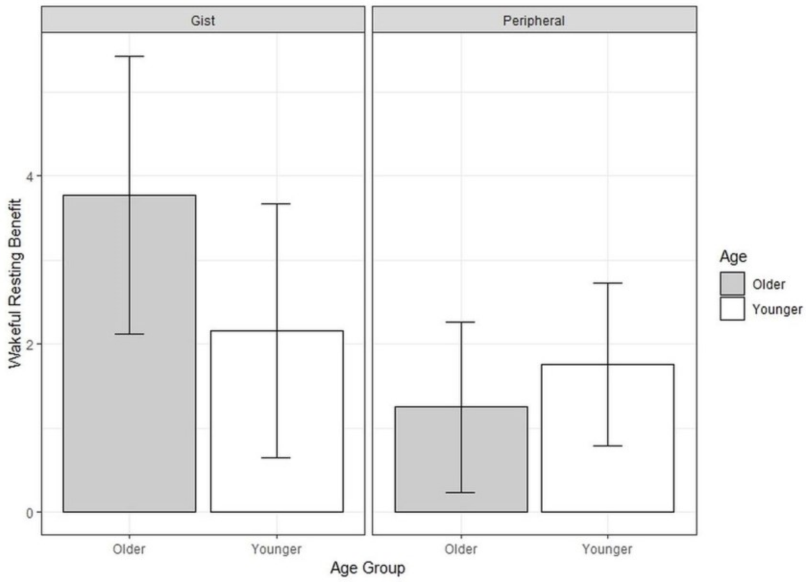
Gist
Peripheral
Wakeful Resting Benefit
0
2
4
Older
Younger
Older
Younger
Age Group
Age
Older
Younger

Figure captions

Figure 1. Sketch of experimental procedures for the interference and wakeful resting conditions.

Figure 2. Histograms of the mean scores on the three stories for gist and peripheral memory achieved by older and younger adults in interference and wakeful resting conditions with 95% confidence intervals as error bars.

Figure 3. Means of the wakeful resting benefit (difference between wakeful resting and interference scores) achieved by older and younger adults in gist and peripheral memory conditions with 95% confidence intervals as error bars.